DIELECTRIC CONSTANT STABILITY AND ADHESION ENHANCEMENT OF FLUORINATED AMORPHOUS CARBON

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INTRODUCTION

With decreasing device design rules, fabrication methods for thin film multilevel interconnections (MLIs) have become an area of intense research interest in the study of ULSI circuits [1]. In multilevel interconnections, it has been predicted that semiconductor device performance is limited by the resistance-capacitance (RC) delay. Since the reduction of delay time in ULSI devices is difficult because of the large parasitic resistance and capacitance of multilevel interconnections, these large resistance and capacitance must be reduced to achieve high performance. Therefore, copper and low-k-based interconnect technology has become an area of intense research interest in ULSI applications. Fluorinated amorphous carbon is considered one of the most promising materials as low dielectric interlayer materials [2,3]. It has low dielectric constant caused by C-F bonds and thermal stability resulting from the C-C crosslinked structure. In this study, in order to improve the stability and the adhesion of the a-C:F film, nitrogen plasma treatment was applied to as-deposited a-C:F films.

EXPERIMENTAL

The a-C:F films were prepared by an electron cyclotron resonance chemical vapor deposition (ECRCVD) system (AsTeX Model AX 4505) using gas mixture of C_2F_6 and CH_4. The microwave power and deposition during deposition were fixed at 500 W and 200℃, respectively. The post-plasma treatment of the a-C:F films was carried out using N_2 plasma with various plasma treatment powers (150～ 700 W) and times (7.5～ 300 s) after deposition without vacuum breaking. During the plasma treatment, 20 sccm N_2 gas was introduced into a plasma chamber.

Ta film was deposited using DC magnetron sputtering at a pressure below 8×10^{-7} Torr followed by Cu deposition in order to avoid oxidation of the Ta layer. The deposition of both films was carried out at room temperature. The thickness of Ta and Cu films were about 300 Å and 400 Å, respectively.

The dielectric constants of the a-C:F films were measured by determining capacitance-voltage (C-V) characteristics employing a metal-insulator-metal (Pt/a-C:F/Pt) structure at 1 MHz. X-ray photoelectron spectroscopy (XPS) was used to determine the change of elemental distributions and the chemical compositions of the films after the post plasma treatment. The surface energy of a-C:F films was evaluated by contact angle measurements using water (a polar liquid) and diiodomethane (an apolar liquid).

RESULTS AND DISCUSSION

Figure 1 the contact angle and surface energy of the a-C:F films as functions of N_2 plasma treatment power. A sharp decrease in water and diiodomethane contact angle was observed at 150 W of the plasma treatment power, and this value remained nearly constant with the extension of treatment power to 700 W. On the other hand, the surface energy of the a-C:F films increased drastically to about 52.26 mJ/m^2 in plasma treated films at 150 W compared to 28.32 mJ/m^2 of the untreated one, and this value remained nearly constant. These results indicate that nitrogen plasma treatment improves a-C:F surface wettability and makes the film surface relatively hydrophilic.

XPS spectra of the films show that the fluorine concentration of the surface decreases rapidly. The fluorine to carbon ratio of the film surface was reduced from 0.50 to 0.038 with increasing the plasma treatment power. As the plasma treatment power increases, the relative peak areas of both the C-C and the C-CF$_x$ components increase. On the other hand, the relative peak area of the C-F, the C-F$_2$ and the C-F$_3$ components decrease. The fact of larger C-C and C-CF$_x$ peak areas suggests that a portion of C-C crosslinking structure in the film was enhanced.

Table 1 shows the dielectric constant of the a-C:F films as a function of plasma treatment power. The untreated a-C:F film and the plasma treated films have the similar dielectric constants.

Through this study, it was found that the nitrogen post-plasma treatment dose modifies only the surface of the films but not the inner layers of a-C:F films. The surface modification by the post-plasma treatment produce more reactive surfaces and affect the fluorine concentration of the surface, the structure of chemical bonding.

References
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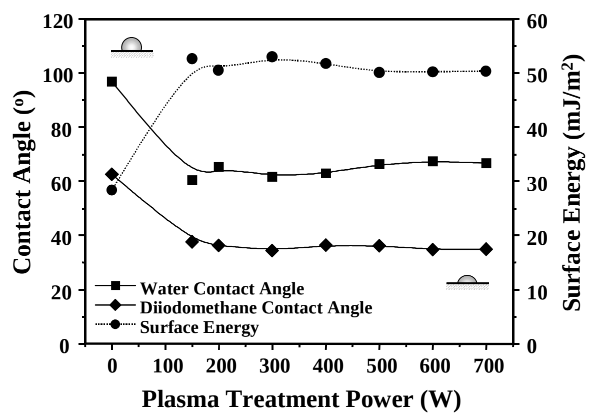

Figure 1. Contact angle and surface energy of a-C:F films as a function of plasma treatment power

Table 1. The dielectric constant of a-C:F films as a function of plasma treatment power

Plasma Treatment Power	Dielectric Constant
as-deposited	2.58
150 W	2.59
400 W	2.60
700 W	2.60